discontinuity pre-eminently evolving under such conditions. Further, a series of cyclones often follows approximately the same path, the surface of discontinuity having been only partly destroyed by the first cyclone, so that it may, after a short period of restoration, serve as a steering surface for the next one.

In the case of a stationary steering surface the path of the center would follow the fixed steering line. But as the steering surface is generally already in motion, we can only assert that the momentary direction of propagation of the center is given by the tangent of the steering line at this center.

Taking the general case of a cyclone propagating to the east, the cold current will cover the ground on the northern and western sides of the center, while the warm current will be able to keep to the ground only in the warm sector, southeast of the center. From there it will flow over the cold current, joining the general western drift in the higher strata.

The general effect of the motion described is that cold air is conveyed to regions previously covered with warm, and there spread along the ground; and that in compensation, warm air is conveyed to previously cold air regions, and there distributed in the higher strata. Generally speaking, therefore, the cyclones may be said to be links in the interchange of air between the polar regions and the equatorial zone. This interchange, which is effected continuously in the zone of the trade winds, takes the irregular and intermittent character of cyclonic motions in the latitudes outside the high-pressure belts limiting the trade winds.

The results to which we have arrived may to a great extent be considered as a verification of views developed theoretically by Margules:[4] "The phenomena of motion in great storm areas that we call cyclones are less intelligible than those of the squalls. But these also, at least in middle and higher latitudes, consist of warm and cold masses of air lying adjacent to each other horizontally; cold air often spreads out over the earth in the lower strata behind the passing storm. It is therefore not unlikely that these storms are fed by the potential energy of an initial stage . . . . Otherwise these results verify certain traits in different older theories of cyclones, while they disprove other traits.

We are reminded both of Dove's old theory of the conflict between polar and equatorial currents as well as of the modern "counter current" theory of Milham.[5]* Ferrel's convectional theory is confirmed in its essential part, in as much as the ascending air in the cyclones is warm. This warm air, however, does not form a central core, but comes from the side, covering a warm sector. The general argument against the theory of Ferrel, that statistical investigations have proved a circular area around the center of the cyclone to be cold rather than warm, does not disprove the principal point, that the ascending air is warm, but only the accidental assumption of the symmetrical structure of the cyclone. The confusion concerning this point led to the paradoxical assumtion that the mounting air in the cyclone is cold and heavy. As under conditions theoretically specified by Sandström,[6] a symmetrical cyclone can really act as a kind of centrifugal pump, lifting the cold air of its central core, this assumption contains no intrinsic contradiction, but can now simply be dropped. While thus an unnecessary element of v. Hann's "driven eddy" theory has to be left out, the general view of this theory, that the cyclones are merely partial phases of the general atmospheric circulation, has been fully confirmed.

[4] Ibid.

[5] Meteorology, Milham, New York, 1912, p. 311.

* Milham attributes this to Frank H. Bigelow. See "The mechanism of countercurrents of different temperatures in cyclones and anticyclones." Mo. Wea. Rev., 1903, 31: 72-84.

[6] J. W. Sandström, Ueber die Beziehung zwischen temperatur und Luftbewegung. Met. Zeits., 1902, 19: 161-171.

POSSIBLE IMPROVEMENTS IN WEATHER FORECASTING.

With special reference to the United States.

By V. BJERKNES.

Probably the most important step that can at present be taken for the improvement of the weather forecasting will be the introduction in the daily weather service of good charts representing the lines of wind flow.

The drawing of these charts presents no special difficulties. When a meteorologist has gained sufficient acquaintance with them, he will draw them as easily and as quickly as somewhat complicated isobaric or isothermal charts. My Gothenborg address [1] and J. Bjerknes's paper [2] give useful hints concerning the use of these charts, and their connection with the weather. But accumulated personal experience will also be of great importance.

These charts will, however, have their full prognostic value only when the observations permit them to be drawn in such detail that the two fundamental lines of convergence of the cyclone, steering line, and squal lline, can be accurately identified.

For this purpose it is necessary that the observations of the wind be made and telegraphed as accurately as possible. In this respect there is occasion for an important improvement in the system of observations in the United States. At present only eight directions of wind are reported. Making the observations of the wind directions as accurately as the conditions of each station will permit and telegraphing in detail the results thus obtained will be an important step in making it possible to draw the true lines of flow.

On the other hand, it will be highly desirable to get a closer network of stations. How far it will be necessary or desirable to go in this respect can only be shown by experience.

Besides about 300 telegraphic stations, the United States has a great number of climatological stations, about 3,000 if my memory is correct.* If all the sewere made telegraphic we should get about the same number of stations in proportion to area as are used in western Norway. As desirable as an expansion on this scale would be, considered as an experiment, it would probably meet with difficulties from the point of view of the telegraphic service; and quite likely it will not be necessary. The close network of stations in western Norway is necessary, partly on account of the complicated topography and partly on account of the exceptional difficulties during the war, when practically no weather telegrams from abroad are received. With the simpler topographical conditions in the United States, and the comprehensive view obtained from the great area of observations,

[1] Weather forecasting. This REVIEW, pp. 90-95.

[2] On the structure of moving cyclones. This REVIEW, pp. 95-99.

* About 4,500.—Ed.

it is probable that much could be accomplished by doubling or tripling the number of the stations. It will, however, be of great importance to have a network of stations along the Pacific coast, with a closeness corresponding to that of the west coast of Norway, in order to be able to catch the arrival of lines of convergence, and thus determine as early as possible the direction which the cyclones will take. A close network of stations will probably also be useful on the Gulf coast.

Even if it might be desirable, it would not be necessary to give these new stations the same complete instrumental equipment as the old ones. Their most important task would be to give as accurate reports as possible:

I. On the direction and strength of wind, from which to determine the lines of flow.

II. On the temperature, from which to determine the sudden rise or fall at the lines of convergence.

Concerning further observations which may be desirable, e. g., concerning rain at or within sight of the station, on the appearance of the sky, etc., or concerning special observations which may be had from the coast stations and from favorably situated mountain stations, the reader is referred to my Gothenborg address.[3]

Concerning the advantages which might be obtained by this extension of the weather service it can be stated that if, as in western Norway, the observations in the morning are made the basis of forecasts for the rest of the same day, these forecasts may be given with great confidence and in great detail for the different districts, usually with an indication of the time of the day when the rain will begin.

It will be more difficult to express an opinion as to how forecasts for the following day, or a still longer period, would succeed. For in this field we have had no experience in Norway, where in the present abnormal conditions the duration of the forecast had to be limited to the utmost. But we have every reason to believe that conditions even in this respect will prove favorable on an area of observations of an extent as great as that of the United States.

It is of course very difficult for me to estimate the cost of the indicated change of the weather service in the United States. If, as I believe, a sufficient number of climatological stations already exist, the main expense would be on account of the increased telegraphic service.

It may be instructive to report that the Norwegian Government granted 70,000 kroner ($18,667) for experiment with the weather forecasting this past summer [1918] in western Norway according to the new system.

The main expense was for the telegrams, and the sum turned out to be sufficient for the purpose, even though it concerned a new start rather than an extension of a system already existing. The grant was given principally on the ground that even if there should result an increase of only 1 per cent in the returns from agriculture the expense given for the weather forecasting would be many fold covered.

[3] Pp. 90-95 of this REVIEW.

SYNOPTIC STUDY OF HYDROGRAPHICAL PHENOMENA.

By Dr. HANS PETTERSSON.

[Dated: Göteborgs Högshole, Sweden, Dec. 24, 1918.]

In a previous communication[1] to the MONTHLY WEATHER REVIEW I have set out the reasons for an increased intensity of hydrographical observations in coastal waters and have also described some new technical resources evolved for that purpose.[2]

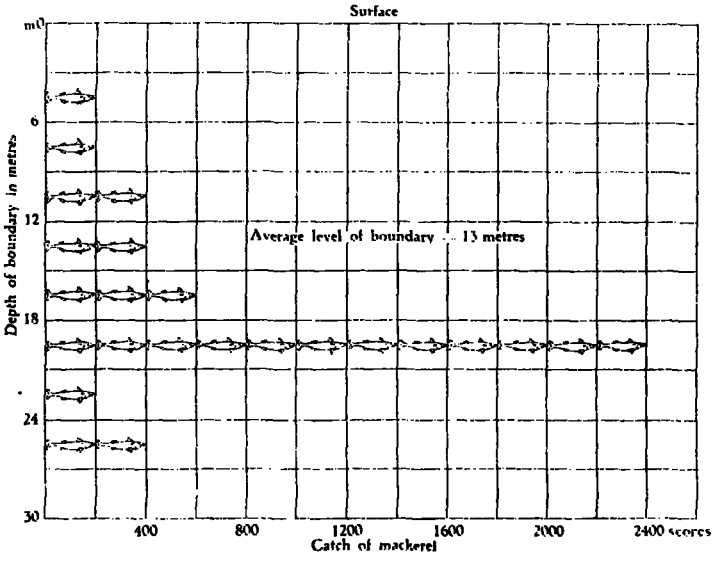

FIG. 1.—Relation of the catch of mackerel to the depth at which dense sea water is found.

Mainly through the daily soundings taken for nearly a decennium at Bornö Station in the Gullmarford, the first example of continuous hydrographical observations on record, the surprising variability of the situation in coastal waters was first proved and investigated. The close connection existing between similar changes and biological phenomena has repeatedly been confirmed by Swedish hydrographers, by G. Ekman and O. Pettersson for the rich catches of herrings made in winter off the west coast of Sweden and by the author for the catch of mackerel in summer. In figure 1 a graphical representation is given of the catches of mackerel made at Bornö during the summers of three years as a function of the simultaneous depth of the 30 per cent boundary in the fiord; nearly 1,000 scores were caught when the boundary was below its average level against less than 1,000 scores when it was above the average.

In winter, when these movements are especially large and rapid, the disappearance from the surface of water of North Sea origin (warm and salt) replaced by a sheet of ice-cold brackish water from the Baltic, or vice versa, will have a marked effect on the local air-temperature, the freezing of the fiords or the breaking up of their ice. The great scientific interest which these internal movements in the sea command is thus further enhanced by their bearings on practical questions.

Now the results from the investigation at Bornö are open to the objection that the displacements of the boundary observed at that place may be a *local* phenomenon limited to the Gullmarfiord—i. e., of the nature of the internal seiches studied in Scotch lochs by Wedderburn.[3] The best method of proving or disproving this suggestion is obviously to make continuous observations at one or more other points on the coast parallel to those at Bornö. A first attempt in this direction was made by the author

[1] MONTHLY WEATHER REVIEW, 1917, p. 159.

[2] The new Amundsen N. polar expedition has been equipped with a set of these instruments, its hydrographer, Dr. Sverdrup, studying their use at my institution before starting.

[3] Proc. R. Soc. Edinb. Vol. 29, p. 98.